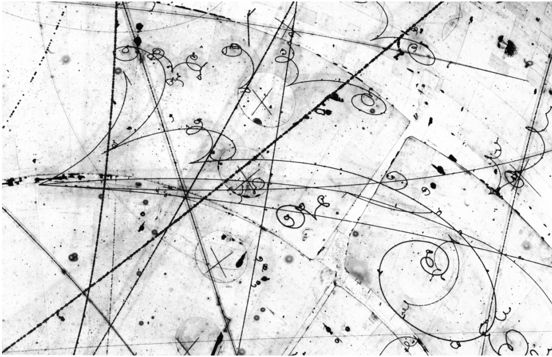
ColorCast: Deterministic Broadcast in Powerline Networks with Uncertainties



Particle collision tracks

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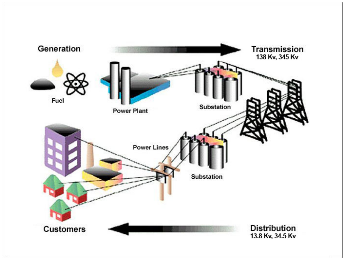
Task

A set of electrical substations V

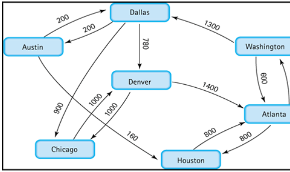
- All connected through a powergrid.
- Use the powergrid to communicate
- One (say s) has something to say
- Needs to **broadcast** it to **all** other stations
- Discrete time model

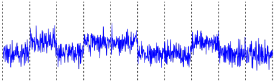
Metric= Broadcast time: Number of rounds between the first send and the last receive.



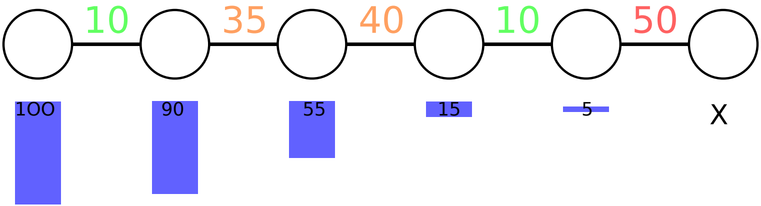
Model: Very generic

- A **weighted Graph** $G(V, E, d)$ of interconnected substations. Weight denotes edge length.
- A noise distribution $\rho^t : E \mapsto [0, \rho_{max}]$ between any stations
  - Can be asymmetric $\rho^t(u, v) \neq \rho^t(v, u)$
  - Can vary in **any** way provided $\in [0, \rho_{max}]$

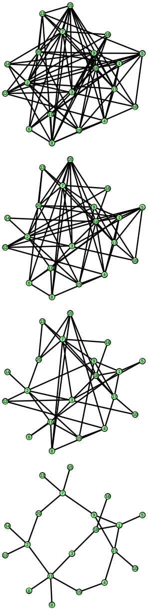




- Any noise impact function $f(d, \rho^t)$
  - Provided f is both monotonic if f and ρ
  - ...and $f(d, \rho) \geq d$
  - a "virtual length" of each link at each timestep



Model (2)



$< G(V, E, d), \{\rho^t, \forall t\}, f >$ defines a dynamic graph:

$$G_1, G_2, G_3 \ldots G_t \ldots$$

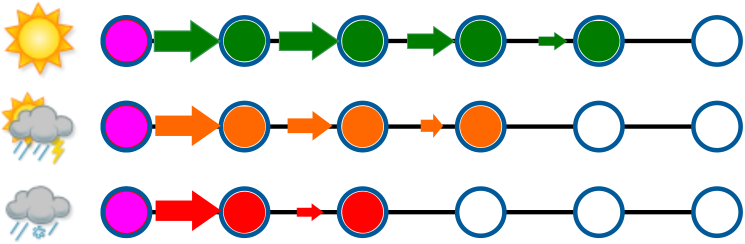
We focus on two special graphs:

- $G_{com}^{\perp} = G_t$ when $\rho^t(e) = \rho^{max}, \forall e \in E$
  $=$ **worst case** communication
- $G_{com}^{\top} = G_t$ when $\rho^t(e) = 0, \forall e \in E$
  $=$ **best case** communication

N.B.: We require $G_{com}^{\perp}$ to be connected

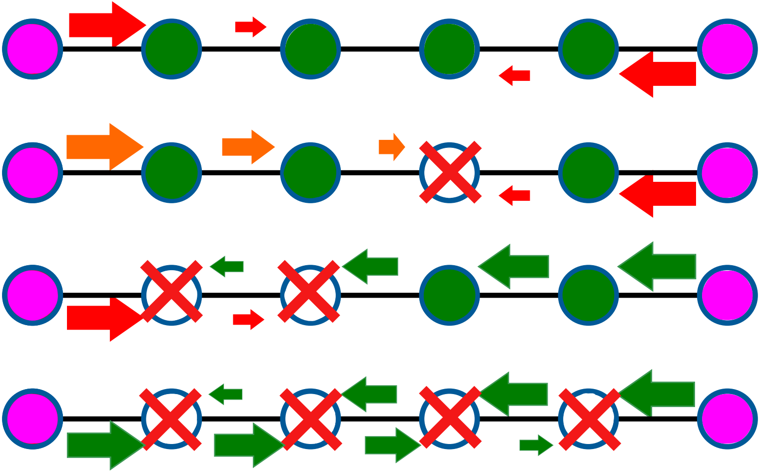
Problem

Unknown ranges



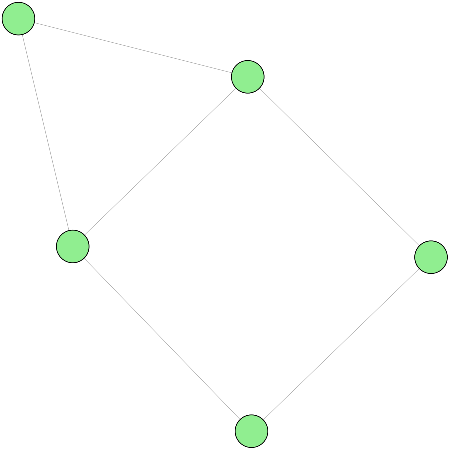
Problem

Unknown range + Collisions = Problem

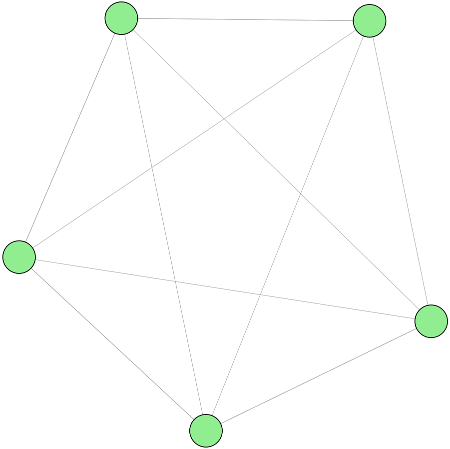


Second Problem

Physical grid $\neq$ communication network

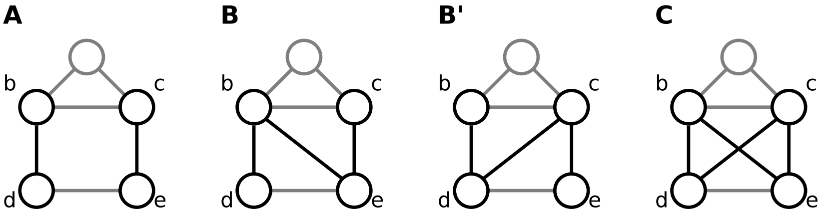


(outer)Planar graph !



Non-Planar graph !

Traditional Broadcast Protocols Fail



	A	B	B'	C
A	OK	e: Col.	d: Col.	e, d: Col.
B	e: $\emptyset$	OK	e: $\emptyset$	e, d: Col.
B'	d: $\emptyset$	d:$\emptyset$	OK	e, d: Col.
C	d/e: $\emptyset$	OK/ e:$\emptyset$	d:$\emptyset$ / OK	OK

Figure: *Col.* stands for collision and $\emptyset$ stand for no message received.

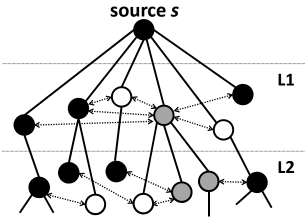
Algorithm

"Hope for worse, prepare for best"

- Create a Connected Dominating set (CDS) of $G^{\perp}_{com}$
- Divide it into layers according to distance to s
- Schedule each layer separately: i and j in layer k can send at the same round if:

$$d_{G^{\top}_{com}}(i,j) > 2$$

(aka a coloring of $(G^{\top}_{com})^2$ $\Rightarrow$ColorCast)



Analysis

- $d_{G^{\top}_{com}}(i,j) > 2 \Rightarrow$ **No collision**
- No collision, no coin toss $\Rightarrow$ **Deterministic**
- **Correctness:** Layers = CDS and no collision $\Rightarrow$ after last layer send, broadcast is over
- **Complexity:** Max nodes in the CDS= n, worst case none can talk at same round $\Rightarrow \theta(n)$

Observations:

- (Somehow) Asymptotically optimal when $D = n$
- No hidden factors !

Simulation Results

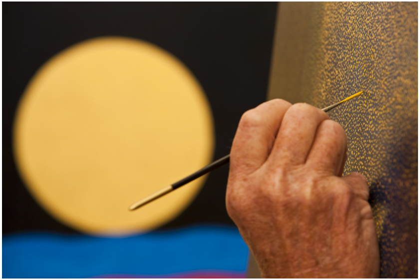
Algorithms

ColorCast

- Deterministic
- No collision
- $\theta(n)$

Decay

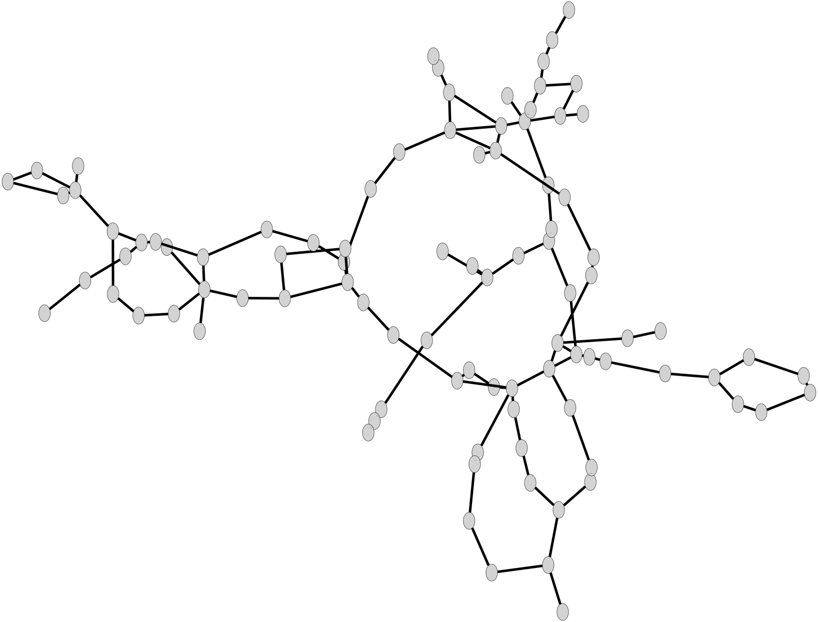
- Randomized
- $O(D + log(n/\epsilon)log(\Delta))$
- We set $\epsilon = 1$



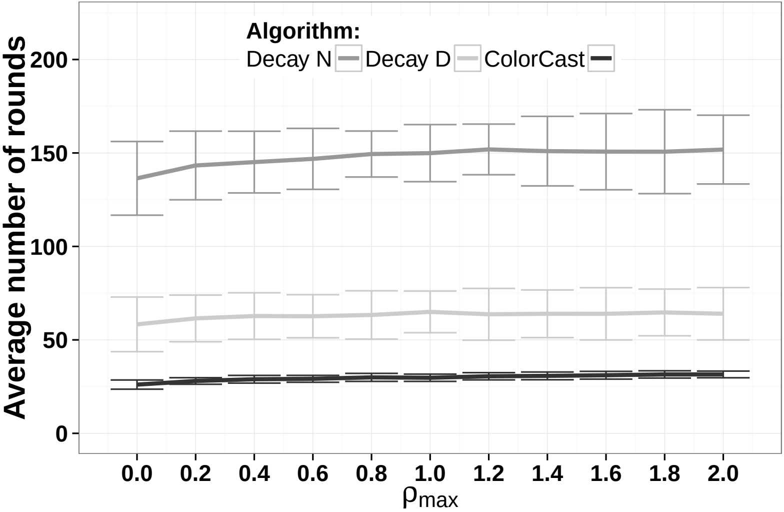
vs

- 3 different scenarios: No noise, Random noise, Max noise
- Averages = 100 runs
- Bigger networks created by "copy-pasting"

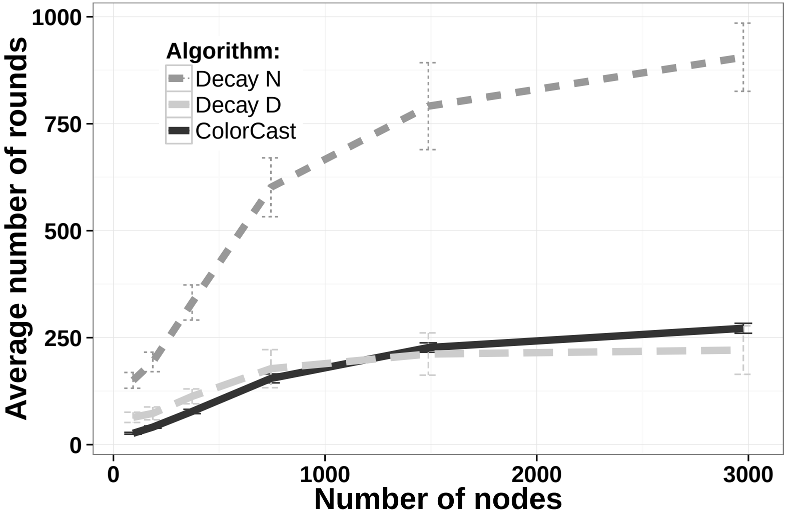
Simulation Topology



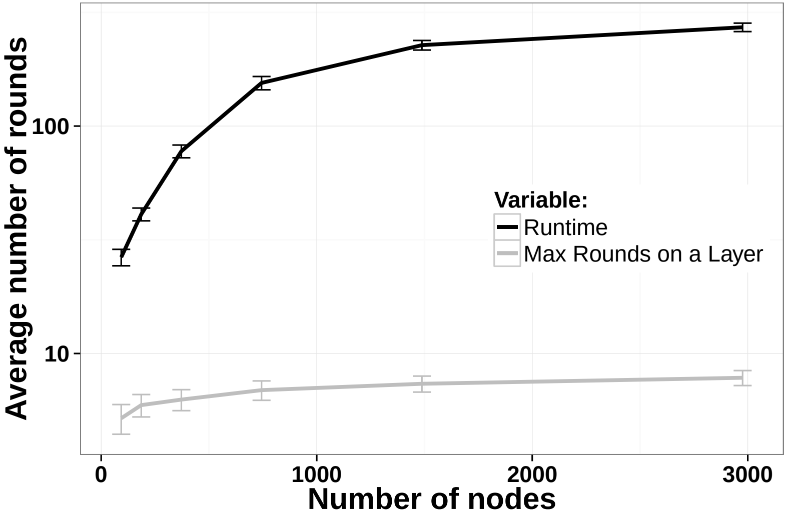
Simulations



Simulations -2



Simulations -3



Conclusion

We presented **ColorCast**

- Simple, deterministic algorithm
- Guaranteed convergence and runtime
- Performs well in practical scenarios

Further:

- Identify graph classes where things go well
- Deterministic lower bound

Takeaways:

- 1.01^n vs n^{400}: Beware of asymptotical complexity!
- A glimpse of dynamism can break cathedrals
- $4\star$ hotel $\not\Rightarrow$ Decent internet